Management Report

STATUS OF THE BALSAM WOOLLY APHID IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK---1976

Management Report No. 20

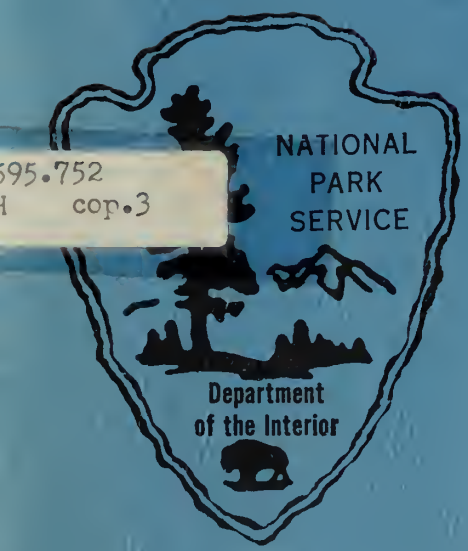
NATIONAL PARK SERVICE

SOUTHEAST REGIONAL

UPLANDS FIELD RESEARCH LABORATORY

GREAT SMOKY MOUNTAINS

NATIONAL PARK



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ACKNOWLEDGMENTS

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We express our appreciation to all of the people and agencies that have supported our work.

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IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK
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INTRODUCTION

The balsam woolly aphid (Adelges piceae (Ratz)) is a tiny sucking insect that was introduced into North America from Europe about 1900. First identified in Maine and Maritime Canada, it has spread across the continent rapidly, causing extensive damage to most native firs.

Since 1957 the aphid has become an increasingly serious pest of Fraser fir (Abies frasei (Pursh) Poir.) in the Southern Appalachian mountains (Amman and Speers, 1965). It was first discovered on Mount Mitchell and later found on Roan Mountain in Northeast Tennessee and on Mount Sterling in the Great Smoky Mountains National Park. In addition to colonizing these large areas of Fraser fir, the insect has been observed in small and more scattered stands, e.g., Grandfather Mountain, North Carolina and along the Blue Ridge Parkway. Due to the immediate adverse effect of the insect upon the host, and the relatively small stands of fir in disjunct patterns throughout the Southern Appalachians, the balsam woolly aphid (BWA) seriously threatens the very existence of Fraser fir. This species may soon be a candidate for an "endangered species" list.

BIOLOGY OF THE BALSAM WOOLLY APHID

The balsam woolly aphid is not a true aphid, rather it is a member of

Chermidae, or "jumping plant lice." Characteristics of this family include

1) feeding exclusively on plant sap,

2) specialized mouthparts primarily the slender rod-shaped stylet which is inserted into the plant for feeding, and

3) complex life cycles involving gradual metamorphosis through several morphological stages.

Adults of the species are less than 1 millimeter in length; their round, soft bodies are covered with long, curling, white threads that matt together in a protective covering of the characteristic "wool."

The BWA population consists entirely of wingless females which reproduce parthenogenically. Several factors contribute to the insects phenomenal capacity for population increase.

1) The average number of eggs laid by each adult is 100.

2) Survival from egg to adult is around 60 percent.

3) Up to four generations per year may reach maturity in the relatively moderate climate of the Southern Appalachians.

4) There are no natural or introduced predators of any consequence.

5) There appears to be no climatic control; the necessary extremes of temperature and/or humidity rarely occur in this area.

6) Host resistance has not been identified in Fraser fir.

The life cycle of each individual consists of an egg stage, three nymphal forms, and the adult. A typical seasonal pattern might begin in the autumn; adult insects deposit egg masses on the bark of the host tree. Emerging from the egg case, the nymph or crawler is capable of independent move-

ment and soon locates a suitable spot on the bark. After inserting the stylet, it becomes dormant for the winter. In the spring, the individual passes through two additional nymphal stages, differing primarily in size, and then becomes an adult, all without changing location on the host. This cycle may be repeated two or three times during the summer, depending upon environmental conditions (Balch, 1952).

The dissemination of insects that are passively dispersed is determined primarily by the availability of a mobile stage and the direction and velocity of the wind, although other vectors may be involved. In the case of the balsam woolly aphid, dispersal occurs during the egg and crawler stages and is largely passive; although capable of crawling over 100 feet per day and remaining motile for at least eight days, most crawlers settle close to their parent within a few hours of hatching. However, eggs and crawlers may be easily dislodged from the tree and carried over 300 feet by surface winds and several miles by vertical air currents (Balch, 1952). BWA are able to persist on cut logs long enough to be spread by logging activities; the establishment of crawlers on logs cut for several months indicates that they are unable to distinguish between suitable hosts and those which are about to become unsuitable; the first visual indication of unsuitability is the dying out of settled insects (Atkins and Wood, 1968). Distribution of insects on an individual tree depends upon light, temperature, gravity, and accessibility of young, tender parenchyma at wounds, lenticels and crevices, and areas stimulated by the feeding of other woolly aphids.

HOST-INSECT INTERACTIONS

The balsam woolly aphid obtains its complete diet from carbohydrate-rich translocation fluids in the host tree. The feeding of a few such minute insects would hardly disrupt normal plant processes, but the effects are disastrously multiplied by the capacity of the insect to reproduce and rapidly infest a tree. The woolly aphid stylet is inserted between phloem cells, aided by a flow of saliva, and fluids are withdrawn from the tree. Apparently it is this saliva and not the small quantity of fluids removed that causes damage to the tree; the secretions cause formation of abnormal cells in the tissues surrounding the feeding area. These abnormal cells, or "redwood," are a classic symptom of aphid infestation and resemble the compression wood cells that form in trees that lean from vertical. Compression wood cells are larger than normal and thickened so that movement of fluids is severely impeded. This obstruction of the tree's vital processes, perhaps in combination with hormonal imbalance also caused by the salivary secretions, is probably the principal cause of death (Balch, Clark and Bonga, 1964). In heavy infestations, the bark may also die to the cambium, further weakening the tree and providing an entrance for fungal infections.

Infestation symptoms vary among host species; the attack may be concentrated on either the bole or the crown. The crown infestation is more common on balsam fir (Abies balsamea L. Mill) and causes gouting of branches and twigs. Crown efficiency is thereby reduced, but recovery is possible if the aphids die. Trees may reach maturity while supporting a moderate population for many years. Bole infestations are usually more severe, causing death

within a few years. Unfortunately bole attack is the most common on maturing Fraser fir, although some reproduction has been observed with gouting on the twigs. Unless severely infested, many of these saplings appeared to be recovering and some had substantial height growth because the overstory had been removed during the infestation.

Once the infestation has built to a substantial level on the host, there is a marked reduction in tree vigor and the crown begins to fade from the characteristic blue-green of healthy fir to a dull, yellow-green. Color changes are subtle at first, becoming more apparent as tree vigor declines. As death approaches the crown becomes bright red-brown, a common sign of severe insect or disease damage in conifers, e.g., pines infested by southern pine bark beetles. The red-brown fades to dark brown but the leaves persist for some time. BWA is an obligate parasite, unable to maintain itself on trees of drastically reduced vigor, consequently large populations are not usually found on trees in the red-brown stage.

Each tree presents a different combination of phenotypic characteristics, e.g., bark thickness, tree form, height, overall vigor, position in the stand, and accordingly provides a unique environment for aphid feeding, protection, and reproduction requirements. Thus trees differing in certain characteristics may differ in their ability to support aphid populations and in their levels of susceptability or resistance to attack. The relationships between levels of aphid infestation and selected characteristics of individual trees and the sites on which they grow will continue to be an objective of our research program.

DISTRIBUTION OF THE BALSAM WOOLLY APHID IN THE PARK

Color infrared aerial transparencies were used to obtain the distribution of BWA in the Park on May 19, 1976. Photographic conditions were near perfect and 24 x 24 cm transparencies were obtained. The air was dry, there were no clouds, and the ground was clearly visible. The only problem was the irregular flight lines caused by strong northwest winds, thereby creating voids in coverage between some flight lines. Refer to Appendix I for a complete description of photo interpretation techniques and sampling strategies.

Balsam woolly aphid populations are distributed throughout the spruce-fir forests in the Great Smoky Mountains National Park (See Figure 1). The transparencies showed BWA activity to be most concentrated toward the northeast section of the Park, but fieldwork throughout the summer confirmed the presence of BWA in many areas that appeared to be uninfested on the transparencies. Apparently the insect population and damage levels had not grown to an intensity that could be detected by the film, which distinguishes fading tree crowns. Vigor of trees in the new infestation areas had not decreased sufficiently for detection.

The most extensive damage, where nearly 100 percent mortality had occurred, was the Mount Sterling area and the central portion of the Balsam Mountains (Big Cataloochee to Luftee Knob). The soutnern end of the Balsam Mountains (Spruce Mountain to Balsam Mountain Campground) had over 50 percent fir mortality and most living fir trees were heavily infested by BWA. The northern extent of the Balsam Mountains had less mortality than the

southern end, but the majority of fir were infested.

Balsam wooly aphid damage along the State-line Ridge was not as severe as on Mount Sterling or the Balsam Mountains. Generally, the intensity of BWA infestations along the State-line Ridge followed a decreasing gradient beginning in the north with high mortality and lessening toward the southwest.

The Mount Guyot area had dead and dying trees on all slopes near the transition with hardwood. There were patches of intense BWA infestation on the east and northeast slopes, and some stems near the summit had BWA; there were few fading crowns there, however. The BWA was well-established in fir stands from Tricorner Knob west to Peck's Corner, including the major spur ridges. These infestations were primarily at the spruce-fir transition with hardwoods and fir mortality is less than on Mount Guyot.

The aphid infestation in the Laurel Top to Mount Kephart area were scattered and not well developed. BWA had not had enough time to complete colonization plus the area supported fewer fir trees. However, no BWA were observed in the pure fir stands on the summits of Laurel Top and Mount Kephart.

The Mount LeConte area had a few small, scattered patches of BWA activity on all its slopes. The northeast slope had the highest concentration of aphids but mostly at the lower elevations of fir. There were no observed aphids near the summit. Scattered infestations occurred along the Boulevard between Mount LeConte and Mount Kephart.

This past summer was the first time that highly visible BWA activity occurred in the area from Newfound Gap to Clingmans Dome, an area of intense visitor use. Many red-brown firs were visible along and from the road.

Scattered infestations were found along the State-line Ridge and on most of the spur ridges including Sugarland Mountain. Aphids were found in the fir stand on the summit of Mount Collins, but most of the infestations were at lower elevations. Infestations were found on Noland Divide, Forney Ridge, and the south slope of Mount Buckley, thereby ringing the North Carolina side of the Dome. The pure fir on the Dome's summit was not infested when the fieldwork started in June.

One frequently repeated observation was that initial infestation development occurred at the lower elevations of fir stands. In nearly every case where the whole mountain was not heavily infested, the best developed BWA patterns were near the spruce-fir transition with northern hardwoods. Furthermore, the transparencies did not show fading crowns toward the summit from the hot-spots, yet reconnaissance revealed developing stem infestations many yards above the hot-spots. These crowns will fade in time as the infestation moves through the entire stand.

The reasons for this development pattern were less clear. It could be that wind eddies were such that most of the BWA were deposited at somewhat lower elevations on the leeward side of the ridge; those that land in the hardwoods cannot complete their life-cycle, but those that land on fir initiate infestations. Or it could be that due to the extreme weather near the summit, those aphids that landed there had a low survival, resulting in noticeably slower infestation development. There may also be differences in host acceptability across the elevation range in fir stands.

Results from Mount Sterling force us to expect the worst for those pure fir stands on Clingmans Dome, Mount LeConte, Mount Guyot, and other 6000

foot peaks. Park Service records show that initial infestations on Mount Sterling were near the hardwood transition along Baxter Creek trail plus west-southwest of the summit. Successive development of the infestation moved toward the summit in the years following abandonment of control efforts. Today there are just a few live spruce and many long-dead fir snags on Mount Sterling (Figure 2). This stand has had 19 years of BWA presence but the pattern was probably completed several years ago.

Albeit the sample of Mount Sterling is limited, it can be speculated with good reason that similar communities (LeConte, Guyot, and the Dome) will follow similar development of BWA infestations. Therefore, in the absence of effective control measures, the important stands of fir in the Park will be decimated by the BWA in 10 to 15 years, if not sooner.

IMPACT OF THE APHID IN THE PARK

The impact of BWA on Fraser fir in intermediate-aged to mature stands is death of the fir. In heavily infested stands no healthy fir, excluding advanced reproduction, has been found; those that aren't dead are heavily infested and declining rapidly. However, there appears to be a less clear relationship between BWA and fir advanced reproduction.

In stands where the overstory was infested, much of the reproduction had aphids. Undoubtedly gravity was the dissemination mechanism and although most seedlings and saplings never supported a large population of aphids, some mortality occurred in these small trees. Seedling mortality did not appear to be substantial; there were many stands with dead overstories and thousands of seedlings per acre. Seedling mortality was most prevalent in

those stands that maintained a heavily infested overstory for several years. The resulting constant dropping of aphids to the understory was the main source of seedling infestation build-up. Limited observations did not reveal reproducing aphids on fir reproduction; there may be problems of BWA reproducing on trees of such minimal nutritive status, but such were not investigated here. When aphids ceased to drop on the reproduction from the overstory, some trees actually survived the first attack and started growing again (see Figure 3).

In stands on Mount Sterling that once had a dense overstory, advanced fir reproduction had not developed much height; there were thousands of small seedlings per acre but few had received enough light to start active height growth under the parent stand. When the aphids killed the overstory releasing the reproduction from the competing overstory, the seedlings began rapid height growth (see Figure 4). Similarly, Fraser fir seemed to be replacing itself with the release of advanced reproduction on other peaks, especially on northern aspects. However, on more southern exposures or in stands that lacked advanced fir reproduction, competing vegetation was well-established in the understory, e.g., Sambucus, Rubus, Acer and Betula plus much herbaceous growth.

MANAGEMENT RECOMMENDATIONS

At this point in our investigation facts are less numerous than speculative ideas. However, there are some impressions that can be given.

1. The balsam woolly aphid has infested Fraser fir throughout the fir distribution in the Great Smoky Mountains National Park and will remain in residence without more effective controls than those currently available.

2. Firs of intermediate-ages or those more mature are susceptible to aphid infestation and die in just a few years. Our field experience has not revealed trees with apparent natural resistance.

3. Fir advanced reproduction responds to BWA attack with variable results, some die but some recover to grow again when aphid attacks cease. The aphids do not seem successful in building and maintaining an infestation on seedlings.

What is the future of Fraser fir in the Smokies? The seed-bearing trees will soon be gone, leaving advanced reproduction in scattered areas. Will the second crop be attacked by BWA before it has a chance to regenerate? Will Fraser fir join the American chestnut as a remnant of an earlier time? There are no immediate answers to these questions but the important management problems they represent need immediate attention and planning. At best the future might be predicted with speculation, but few of us can offer facts. Based upon our incomplete investigation, we tender these management recommendations.

1. The risks of regenerating an area utilizing advanced reproduction concomitant with greatly increased fuel accumulations are high and obvious. One fire at any stage in the new stand development will

eliminate the fir; there are no seed trees left to replenish the burned reproduction.

2. Increased fire protection in those areas where Fraser fir have regenerative potential is a must if the type is to be preserved. Other species can readily replace both spruce and fir. It could be entirely academic as to what size the fir must attain before the aphid will attack; if fires precede the aphid, it won't matter.

3. Recognizing that fir stands occur on the summits of the highest peaks and that lightning tends to strike the same places, increased surveillance may be the first line of defense. However, far more fires start from people activities in the East than from lightning strikes. Closure of the woods during dry periods may be required. Increased awareness of the danger involved should be directed toward those that use the back-country. Trail relocation into stands of hardwood would reduce people incidence in the spruce-fir zone.

4. In areas of high visitor use, programs to lessen the danger from existing fuels would be appropriate. Felling snags and scattering the tops would lessen the hazard through increased decomposition rates. Additionally these areas would be more aesthetic.

5. To our knowledge, there are no aphid control techniques that are compatible with stated Park Service objectives. The effective ones all involve spraying with various pesticides.

6. Artificial regeneration, by planting fir seedlings or direct seeding fir seeds, is a definite possibility. However, as long as the

BWA is anywhere in the Park, these new plantings would be likely for attack. If at some future time the aphid population dies out for lack of a host, seeding or planting could replenish the fir until the winds blew the wrong way again and dumped the aphid back into the Great Smokies. There can be no guarantee that the Southern Appalachians will be isolated from new infestations.

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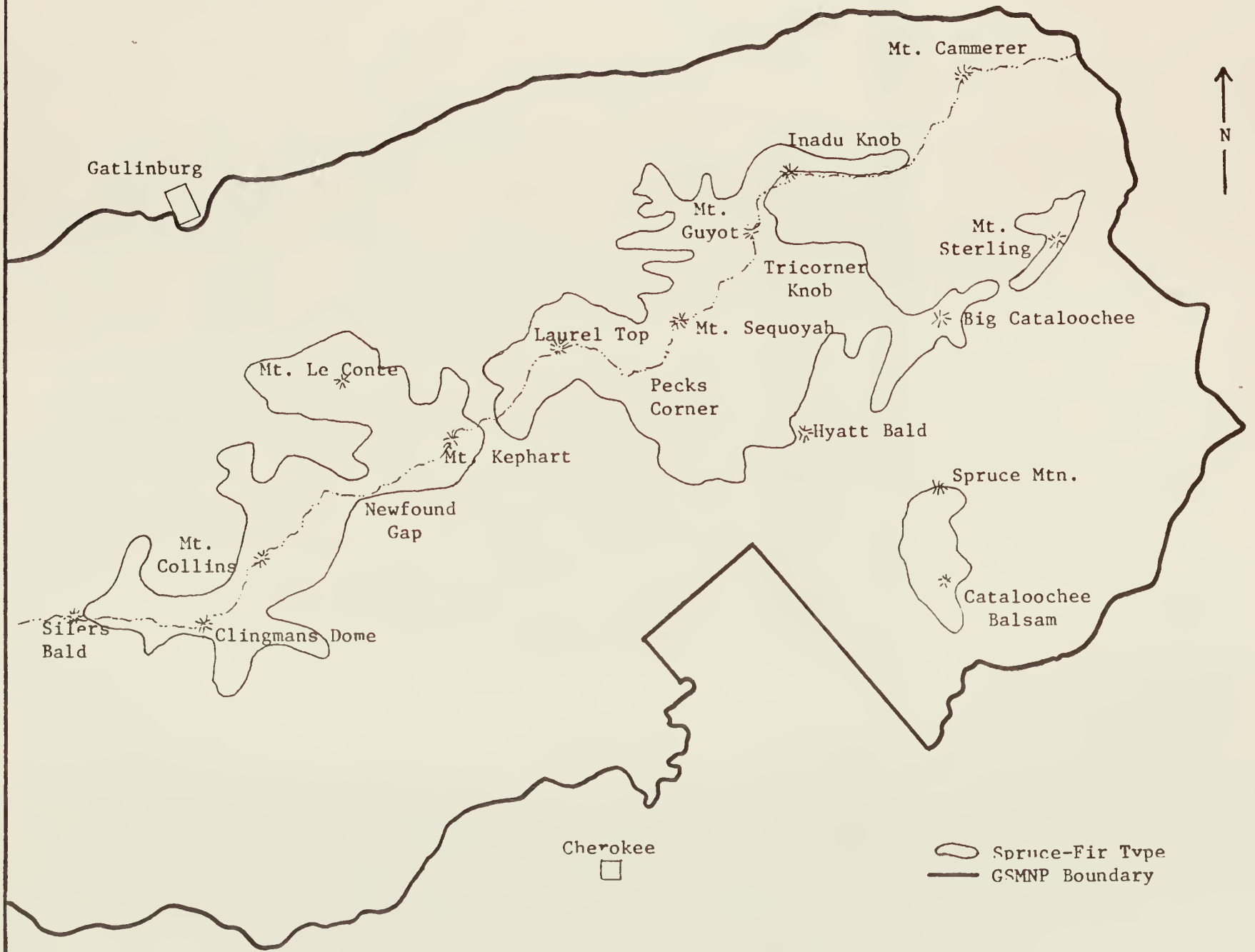
Figure 1. Spruce-Fir distribution in the Great Smoky Mountains National Park.

Balsam woolly aphid damage is total on Mount Sterling and very severe in the Big Cataloochee, Cataloochee Balsam and Inudu Knob areas. There is a general decrease in the intensity of BWA damage from Mount Guyot to Clingmans Dome.


Mt. Cammerer
Inadu Knob
N
Gatlinburg
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Guyot
Mt.
Sterling
Tricorner
Knob
Big Cataloochee
Laurel Top
Mt. Sequoyah
Mt. Le Conte
Pecks
Corner
Hyatt Bald
Mt. Kephart
Spruce Mtn.
Newfound
Gap
Mt.
Collins
Cataloochee
Balsam
Silers
Bald
Clingmans Dome
Cherokee
Spruce-Fir Type
GSMNP Boundary

Figure 2. The view toward Big Cataloochee from Mount Sterling.

The dead fir snags will decompose only slowly until they fall and are covered by the developing understory.

Figure 3. Fraser fir sapling that recovered from attack by the balsam woolly aphid.

Note the compaction of growth whorls just prior to the spurts of the last two years. Compression wood in the stem confirmed several years of aphid infestation.

Figure 4. Dense Fraser fir reproduction that has been released from the parent overstory by the balsam woolly aphid.

Notice the increasing length of the terminal leader on the larger seedlings.

APPENDIX I

DISTRIBUTION AND IMPACT OF THE BALSAM WOOLLY APHID IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

INTERIM PROGRESS REPORT 1

OCTOBER 31, 1976

Contract with
The University of Tennessee
Department of Forestry

DISTRIBUTION AND IMPACT OF THE BALSAM WOOLLY APHID IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

INTERIM PROGRESS REPORT 1

In accordance with our contract dated May 1, 1976, the following report reflecting the recently accomplished procedures and events is respectfully submitted. Results and inferences are not included because analysis is not complete.

AERIAL PHOTOGRAPHY

Color infrared aerial photographs were necessary to locate balsam woolly aphid (BWA) infestations and to estimate the size and intensity of infestation. This tool saved at least one field season of field reconnaissance.

The Forest Pest Management personnel of Southeastern Area, State and Private Forestry in the U. S. Forest Service were contacted to develop specifications for aerial photography. A May 1976 trip to Ashville identified vegetation types, desirable flight patterns, and appropriate photo scales. Request for cooperative assistance from the Atlanta office of NPS, secured the aerial photography at no cost to the project. The developed infrared transparencies were delivered to Knoxville during the third week in May 1976.

Photo analysis was done over a light table and with some magnification. Analysis included:

1. Photo centers were located on 1:24000 topographic maps for reference,
2. BWA active infestations were identified and placed within approximate stand units corresponding stands of spruce-fir; and

3. the apparent distribution of spruce-fir was identified and partitioned into stand units.

Our "stand units" were not always defined as distinct and separate biological communities, rather we identified stand units based on convenient topographic relief and accessibility. For example, we frequently selected stand units to correspond with small watersheds containing spruce-fir, especially if there was an associated infestation.

SAMPLING STRATEGY

The entire distribution of spruce-fir was divided into 11 large geographic units for convenience in sampling designation and record keeping. Examples include Clingmans Dome, Mt. Sterling, and Mt. Guyot. These large areas were further partitioned into 224 stand units of approximate size. Each was numbered and characterized according to aphid infestation intensity.

Based upon photo interpretation the following aphid infestation intensities and frequencies were found:

I. Active - dead and dying fir from apparent BWA.
   - A. Light - small infested area and not well-developed (39)
   - B. Medium - infestation well-developed with some dead trees in center (58)
   - C. Heavy - very well-developed infestation pattern with considerable dead fir; multiple patterns likely (26)

II. Dead - abnormally high fir mortality but not "hot" trees in the pattern (5)

A. Light - small spots of dead trees; may not be BWA mortality (8)

B. Medium - larger spots of dead trees with characteristic BWA patterns (1)

C. Heavy - large area of dead trees; likely merging of multiple group patterns (1)

III. None - no signs of BWA infestation (87)

Sample selection was made from each infestation category proportionally to the total possible stand units. It was estimated for the sake of sample selection, that 30 stand units could be completed during the field season.

After assigning proportional sample frequencies to each infestation category, stands were randomly chosen to complete the selection. However, ground reconnaissance had shown hemlock as a frequent component in spruce-fir stands at lower elevations. Since many of the stand units without BWA damage were in the lower elevation range of spruce-fir, care was taken to select stands of predominantly spruce-fir. These were found above the range of hemlock.

FIELD WORK

Even in an interim progress report, it seems a shame to condense two months of field work, sometimes under less than optimum conditions, into these few paragraphs.

Once the stand unit had been identified on the transparency and topographic map, approximate sample sites were chosen to cover the range of topographic and vegetation conditions within the stand. Upon reaching the

stand exact plot centers were located and marked on the map. Six plots were taken in each stand unit; this provided adequate coverage plus a full-day job. Excessively steep topography and dense rhododendron understories were avoided.

Plot size was 10 meters square with diagonals in north-south and east-west alignment. Plants less than 4½ feet tall were counted on 1 meter square plots at the 4 corners of the 10 meter plot. A sample data-sheet illustrates the information gathered from each plot.

A random sub-sample of three living fir trees was made on each plot to correlate individual tree characteristics to aphid infestation. Examples of measured and estimated variables are also found on the attached data-sheets.

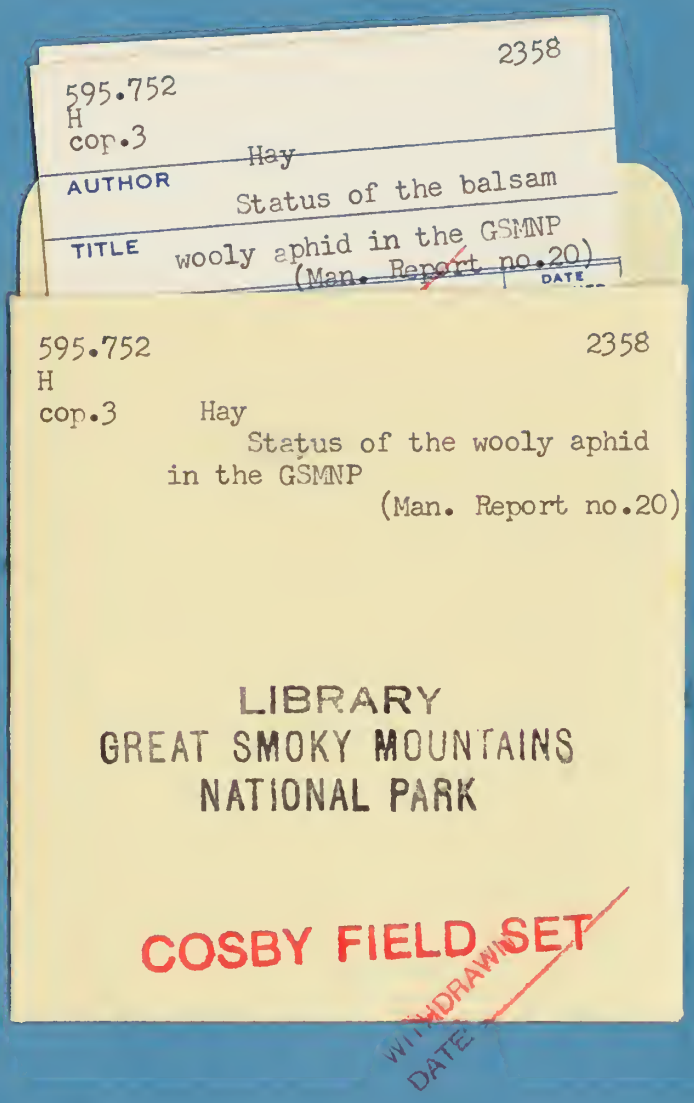
Some degree of permanence was desired for plot center locations. Originally iron stakes were considered, but the excitement of carrying many 18 inch steel rods in packs was more than could be comfortably contemplated. Therefore, a system of placing numbered aluminum labels on four trees each facing plot center was devised. Bearings and distances to the witness trees were recorded. In addition, numerous black and white photos were made to record and describe the plot and the area. Photos were made of distinguishing features along the trail or in the stand to help define plot location. A cataloging system for the 4 X 5 prints has been developed and will become a part of the record system.

There are two graduate students working on this project; one is funded on the assistantship and the second is independent. For about half of the field work, there were three people in the field.

CURRENT WORK

The following tasks are currently in varying stages of completion. Work is continuing on these as well as compiling two theses, one of which should be complete during winter quarter.

1. The photographs for plot description are being printed.
2. Data sheets are being organized, completed, and copies made.
3. Field maps are being up-dated and information transferred to permanent maps.
4. Photo analysis of the infrared transparencies will be done again in view of the extensive ground reconnaissance.
5. Data are being analyzed and statistical procedures developed.



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